

Claims:

1-23. (cancelled)

24. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

- (a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value S and changing the steering command value S from a value S_1 to a value S_2 ;
- (b) computing incremental transition steering angles of four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+\Delta S}$ corresponding to a steering command value $(S_1+\Delta S)$, which is the steering command value S_1 to which an incremental steering command value ΔS has been added , in accordance with the steering constraint condition equations;
- (c) changing steering angles of the four wheels $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+\Delta S}$;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+\Delta S}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+2\Delta S}$ corresponding to a steering command value $(S_1+2\Delta S)$, in accordance with the steering constraint condition equations;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+2\Delta S}$;
- (g) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+2\Delta S}$; and
- (h) repeating above Steps (e)-(g) until the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_2}$ corresponding to the steering command value S_2 .

25. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

- (a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value S and changing the steering command value S from a value S_1 to a value S_2 ;

- (b) computing incremental transition steering angles of four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+\Delta S}$ and incremental transition speeds of rotation of the four wheels $[n_1, n_2, n_3, n_4]_{S_1+\Delta S}$ corresponding to a steering command value $(S_1+\Delta S)$, which is the steering command value S_1 to which an incremental steering command value ΔS has been added, in accordance with the steering constraint condition equations;
- (c) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and speeds of rotation n_1, n_2, n_3, n_4 toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+\Delta S}$ and the incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{S_1+\Delta S}$, respectively;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+\Delta S}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+2\Delta S}$ and next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{S_1+2\Delta S}$ corresponding to a steering command value $(S_1+2\Delta S)$, respectively, in accordance with the steering constraint condition equations ;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and the speeds of rotation n_1, n_2, n_3, n_4 toward the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+2\Delta S}$ and the next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{S_1+2\Delta S}$, respectively ;
- (g) detecting a steering angle conformance, wherein the steering angles of the four wheels $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles of the four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_1+2\Delta S}$; and
- (h) repeating above Steps (e)-(g) until the steering angles of the four wheels $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach the steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{S_2}$ corresponding to the steering command value S_2 .

26. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

- (a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value R which is a distance between a point central to positions of four wheels and a center point of concentric arcs, and changing the steering command value R from a value R_1 to a value R_2 ;
- (b) computing incremental transition steering angles of the four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R_1+\Delta R}$ corresponding to a steering command value $(R_1+\Delta R)$, which is the steering command value R_1 to which an incremental steering command value ΔR has been added , in accordance with the steering constraint condition equations ;

- (c) changing the steering angles of the four wheels $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+\Delta R}$;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+\Delta R}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+2\Delta R}$ corresponding to a steering command value $(R1+2\Delta R)$, in accordance with the steering constraint condition equations ;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+2\Delta R}$;
- (g) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+2\Delta R}$; and
- (h) repeating above Steps (e)-(g) until the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach the steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R2}$ corresponding to the steering command value R_2 .

27. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 26, wherein, when wherein turning-vehicle-travel-paths of the wheels are concentric arcs, the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = -\alpha_3 = \tan^{-1}\left(\frac{L}{R-W}\right)$$

$$\alpha_2 = -\alpha_4 = \tan^{-1}\left(\frac{L}{R+W}\right)$$

where

$\alpha_1, \alpha_2, \alpha_3$, and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

R , which is used as the steering command value, is the distance between a point central to the positions of the four wheels and a center point of the concentric arcs.

28. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 26, wherein when turning-vehicle-travel-paths of the wheels are concentric arcs, the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = \tan^{-1}\left(\frac{2L}{R-W}\right)$$

$$\alpha_2 = \tan^{-1}\left(\frac{2L}{R+W}\right)$$

$$\alpha_3 = \alpha_4 = 0$$

where

α_1 , α_2 , α_3 , and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

R, which is used as the steering command value, is the distance between a point central to the positions of the four wheels and a center point of the concentric arcs.

29. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

(a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value R which is a distance between a point central to positions of four wheels and a center point of concentric arcs, and changing the steering command value R from a value R_1 to a value R_2 ;

(b) computing incremental transition steering angles of the four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R_1+\Delta R}$ and incremental transition speeds of rotation of the four wheels $[n_1, n_2, n_3, n_4]_{R_1+\Delta R}$ corresponding to a steering command value $(R_1+\Delta R)$, which is the steering command value R_1 to which an incremental steering command value ΔR has been added, in accordance with the steering constraint condition equations ;

- (c) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and speeds of rotation n_1, n_2, n_3, n_4 toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+\Delta R}$ and the incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{R1+\Delta R}$, respectively ;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+\Delta R}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+2\Delta R}$ and next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{R1+2\Delta R}$ corresponding to a steering command value $(R_1+2\Delta R)$, respectively, in accordance with the steering constraint condition equations ;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and the speeds of rotation n_1, n_2, n_3, n_4 toward next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+2\Delta R}$ and next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{R1+2\Delta R}$, respectively ;
- (g) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R1+2\Delta R}$; and
- (h) repeating above Steps (e)-(g) until the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach the steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{R2}$ corresponding to the steering command value R_2 .

30. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 29, wherein when turning-vehicle-travel-paths of the wheels are concentric arcs, the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = -\alpha_3 = \tan^{-1}\left(\frac{L}{R-W}\right)$$

$$\alpha_2 = -\alpha_4 = \tan^{-1}\left(\frac{L}{R+W}\right)$$

$$n_1 : n_2 : n_3 : n_4 = \sqrt{(R-W)^2 + L^2} : \sqrt{(R+W)^2 + L^2} \\ : \sqrt{(R-W)^2 + L^2} : \sqrt{(R+W)^2 + L^2}$$

where

$\alpha_1, \alpha_2, \alpha_3,$ and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

n_1 , n_2 , n_3 , and n_4 are the speeds of rotation of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

R , which is used as the command value, is the distance between a point central to the positions of the four wheels and a center point of the concentric arcs.

31. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 29, wherein when turning-vehicle-travel-paths of the wheels are concentric arcs, the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = \tan^{-1}\left(\frac{2L}{R-W}\right)$$

$$\alpha_2 = \tan^{-1}\left(\frac{2L}{R+W}\right)$$

$$\alpha_3 = \alpha_4 = 0$$

$$n_1 : n_2 : n_3 : n_4 = \sqrt{(R-W)^2 + (2L)^2} : \sqrt{(R+W)^2 + (2L)^2} : |R-W| : |R+W|$$

where

α_1 , α_2 , α_3 , and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

n_1 , n_2 , n_3 , and n_4 are the speeds of rotation of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

R, which is used as the command value, is the distance between a point central to the positions of the four wheels and a center point of the concentric arcs.

32. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

- (a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value α_n which is an angle formed between a center line Y between left and right wheels of the vehicle, and a direction of travel of a point P_n, and changing the steering command value α_n from a value α_{n1} to a value α_{n2} ;
- (b) computing incremental transition steering angles of the four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+\Delta\alpha_n}$ corresponding to a steering command value $(\alpha_{n1}+\Delta\alpha_n)$, which is the steering command value α_{n1} to which an incremental steering command value $\Delta\alpha_n$ has been added, in accordance with the steering constraint condition equations ;
- (c) changing the steering angles of the four wheels $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+\Delta\alpha_n}$;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+\Delta\alpha_n}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+2\Delta\alpha_n}$ corresponding to a steering command value $(\alpha_{n1}+2\Delta\alpha_n)$ in accordance with the steering constraint condition equations ;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+2\Delta\alpha_n}$;
- (g) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+2\Delta\alpha_n}$; and
- (h) repeating above Steps (e)-(g) until the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach the steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n2}}$ corresponding to the steering command value α_{n2} .

33. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 32, wherein the steering constraint condition equations for forming a prescribed steering mode are

$$\alpha_1 = -\alpha_3 = \tan^{-1} \left(\frac{L}{x_n + \frac{y_n}{\tan \alpha_n} - W} \right)$$

and

$$\alpha_2 = -\alpha_4 = \tan^{-1} \left(\frac{L}{x_n + \frac{y_n}{\tan \alpha_n} + W} \right)$$

where

α_1 , α_2 , α_3 , and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels;

x_n and y_n are the x and y coordinates of an arbitrary point on the vehicle, P_n ; and

α_n , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle, and the direction of travel of the point P_n .

34. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 32, wherein the steering constraint condition equations for forming a prescribed steering mode are

$$\alpha_1 = \tan^{-1} \left(\frac{2L}{x_n + \frac{L + y_n}{\tan \alpha_n} - W} \right)$$

$$\alpha_2 = \tan^{-1} \left(\frac{2L}{x_n + \frac{L + y_n}{\tan \alpha_n} + W} \right)$$

and

$$\alpha_3 = \alpha_4 = 0$$

where

α_1 , α_2 , α_3 , and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels;

x_n and y_n are the x and y coordinates of an arbitrary point on the vehicle, P_n ; and

α_n , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle, and the direction of travel of the point P_n .

35. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

(a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value α_n which is an angle formed between a center line Y between left and right wheels of the vehicle, and a direction of travel of the point P_n , and changing the steering command value α_n from a value α_{n1} to a value α_{n2} ;

(b) computing incremental transition steering angles of four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+\Delta\alpha}$ and incremental transition speeds of rotation of the four wheels $[n_1, n_2, n_3, n_4]_{\alpha_{n1}+\Delta\alpha}$ corresponding to a steering command value $(\alpha_{n1}+\Delta\alpha_n)$, which is the steering command

value α_{n1} to which an incremental steering command value $\Delta\alpha_n$ has been added, in accordance with the steering constraint condition equations;

- (c) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and speeds of rotation n_1, n_2, n_3, n_4 toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+\Delta\alpha_n}$ and the incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{\alpha_{n1}+\Delta\alpha_n}$, respectively ;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+\Delta\alpha_n}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+2\Delta\alpha_n}$ and next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{\alpha_{n1}+2\Delta\alpha_n}$ corresponding to a steering command value $(\alpha_{n1}+2\Delta\alpha_n)$, respectively, in accordance with the steering constraint condition equations ;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and the speeds of rotation n_1, n_2, n_3, n_4 toward the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+2\Delta\alpha_n}$ and the next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{\alpha_{n1}+2\Delta\alpha_n}$, respectively ;
- (g) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n1}+2\Delta\alpha_n}$; and
- (h) repeating above Steps (e)-(g) until the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach the steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{n2}}$ corresponding to the steering command value α_{n2} .

36. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 35, wherein the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = -\alpha_3 = \tan^{-1} \left(\frac{L}{x_n + \frac{y_n}{\tan \alpha_n} - W} \right)$$

$$\alpha_2 = -\alpha_4 = \tan^{-1} \left(\frac{L}{x_n + \frac{y_n}{\tan \alpha_n} + W} \right)$$

and

$$n_1 : n_2 : n_3 : n_4 = \sqrt{\left(x_n + \frac{y_n}{\tan \alpha_n} - W\right)^2 + L^2} : \sqrt{\left(x_n + \frac{y_n}{\tan \alpha_n} + W\right)^2 + L^2} \\ : \sqrt{\left(x_n + \frac{y_n}{\tan \alpha_n} - W\right)^2 + L^2} : \sqrt{\left(x_n + \frac{y_n}{\tan \alpha_n} + W\right)^2 + L^2}$$

where

$\alpha_1, \alpha_2, \alpha_3$, and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

n_1, n_2, n_3 and n_4 are the speeds of rotation of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels;

x_n and y_n are the x and y coordinates of an arbitrary point on the vehicle, P_n ; and α_n , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle and the direction of travel of the point P_n .

37. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 35, wherein the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = \tan^{-1} \left(\frac{2L}{x_n + \frac{L + y_n}{\tan \alpha_n} - W} \right)$$

$$\alpha_2 = \tan^{-1} \left(\frac{2L}{x_n + \frac{L + y_n}{\tan \alpha_n} + W} \right)$$

$$\alpha_3 = \alpha_4 = 0$$

and

$$n_1 : n_2 : n_3 : n_4 = \sqrt{\left(x_n + \frac{L + y_n}{\tan \alpha_n} - W\right)^2 + (2L)^2} : \sqrt{\left(x_n + \frac{L + y_n}{\tan \alpha_n} + W\right)^2 + (2L)^2} \\ : \left|x_n + \frac{L + y_n}{\tan \alpha_n} - W\right| : \left|x_n + \frac{L + y_n}{\tan \alpha_n} + W\right|$$

where

$\alpha_1, \alpha_2, \alpha_3$, and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

n_1, n_2, n_3 and n_4 are the speeds of rotation of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels;

x_n and y_n are the x and y coordinates of an arbitrary point on the vehicle, P_n ; and α_n , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle and the direction of travel of the point P_n .

38. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

(a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value α_0 which is an angle formed between a center line Y between left and right wheels of the vehicle, and a direction of travel of a point P_0 , which is a center point on a line connecting left and right front wheels, and changing the steering command value α_0 from a value α_{01} to a value α_{02} ;

- (b) computing incremental transition steering angles of the four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+\Delta\alpha_0}$ corresponding to a steering command value $(\alpha_{01}+\Delta\alpha_0)$, which is the steering command value α_{01} to which an incremental steering command value $\Delta\alpha_0$ has been added, in accordance with the steering constraint condition equations;
- (c) changing the steering angles of the four wheels $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+\Delta\alpha_0}$;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+\Delta\alpha_0}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+2\Delta\alpha_0}$ corresponding to a steering command value $(\alpha_{01}+2\Delta\alpha_0)$ in accordance with the steering constraint condition equations;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ toward the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+2\Delta\alpha_0}$;
- (g) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+2\Delta\alpha_0}$; and
- (h) repeating above Steps (e)-(g) until the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach the steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{02}}$ corresponding to the steering command value α_{02} .

39. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 38, wherein the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = -\alpha_3 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} - \frac{W}{L}} \right)$$

$$\alpha_2 = -\alpha_4 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} + \frac{W}{L}} \right)$$

where

α_1 , α_2 , α_3 , and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

α_0 , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle, and the direction of travel of the point Po, which is the center point on a line connecting the left and right front wheels.

40. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 38, wherein the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} - \frac{W}{2L}} \right)$$

$$\alpha_2 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} + \frac{W}{2L}} \right)$$

and

$$\alpha_3 = \alpha_4 = 0$$

where

α_1 , α_2 , α_3 , and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

α_0 , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle, and the direction of travel of the point P_0 , which is the center point on a line connecting the left and right front wheels.

41. (new) A four-wheel-independent-steering-vehicle steering control method comprising:

- (a) using one of variables of steering constraint condition equations for forming a prescribed steering mode as a steering command value α_0 which is an angle formed between a center line Y between left and right wheels of the vehicle, and a direction of travel of a point P_0 , which is a center point on a line connecting left and right front wheels, and changing the steering command value α_0 from a value α_{01} to a value α_{02} ;
- (b) computing incremental transition steering angles of the four wheels $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+\Delta\alpha_0}$ and incremental transition speeds of rotation of the four wheels $[n_1, n_2, n_3, n_4]_{\alpha_{01}+\Delta\alpha_0}$ corresponding to a steering command value $(\alpha_{01}+\Delta\alpha_0)$, which is the steering command value α_{01} to which an incremental steering command value $\Delta\alpha_0$ has been added, in accordance with the steering constraint condition equations;
- (c) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and speeds of rotation n_1, n_2, n_3, n_4 toward the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+\Delta\alpha_0}$ and the incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{\alpha_{01}+\Delta\alpha_0}$, respectively;
- (d) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+\Delta\alpha_0}$;
- (e) computing next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+2\Delta\alpha_0}$ and next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{\alpha_{01}+2\Delta\alpha_0}$ corresponding to a steering command value $(\alpha_{01}+2\Delta\alpha_0)$, respectively, in accordance with the steering constraint condition equations;
- (f) changing the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and the speeds of rotation n_1, n_2, n_3, n_4 toward the next incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+2\Delta\alpha_0}$ and the next incremental transition speeds of rotation $[n_1, n_2, n_3, n_4]_{\alpha_{01}+2\Delta\alpha_0}$, respectively;
- (g) detecting a steering angle conformance, wherein the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ have reached the incremental transition steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{\alpha_{01}+2\Delta\alpha_0}$; and

(h) repeating above Steps (e)-(g) until the steering angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ reach the steering angles $[\alpha_1, \alpha_2, \alpha_3, \alpha_4]_{a02}$ corresponding to the steering command value α_{02} .

42. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 41, wherein the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = -\alpha_3 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} - \frac{W}{L}} \right)$$

$$\alpha_2 = -\alpha_4 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} + \frac{W}{L}} \right)$$

and

$$n_1 : n_2 : n_3 : n_4 = \sqrt{\left(\frac{L}{\tan \alpha_0} - W\right)^2 + L^2} : \sqrt{\left(\frac{L}{\tan \alpha_0} + W\right)^2 + L^2} \\ : \sqrt{\left(\frac{L}{\tan \alpha_0} - W\right)^2 + L^2} : \sqrt{\left(\frac{L}{\tan \alpha_0} + W\right)^2 + L^2}$$

where

$\alpha_1, \alpha_2, \alpha_3$, and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

n_1, n_2, n_3 , and n_4 are the speeds of rotation of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

α_0 , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle, and the direction of travel of the point Po, which is the center point on a line connecting the left and right front wheels.

43. (new) A four-wheel-independent-steering-vehicle steering control method as recited in claim 41, wherein the steering constraint condition equations for forming the prescribed steering mode are

$$\alpha_1 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} - \frac{W}{2L}} \right)$$

$$\alpha_2 = \tan^{-1} \left(\frac{1}{\frac{1}{\tan \alpha_0} + \frac{W}{2L}} \right)$$

$$\alpha_3 = \alpha_4 = 0$$

and

$$n_1 : n_2 : n_3 : n_4 = \sqrt{\left(\frac{2L}{\tan \alpha_0} - W \right)^2 + (2L)^2} : \sqrt{\left(\frac{2L}{\tan \alpha_0} + W \right)^2 + (2L)^2} : \left| \frac{2L}{\tan \alpha_0} - W \right| : \left| \frac{2L}{\tan \alpha_0} + W \right|$$

where

α_1 , α_2 , α_3 , and α_4 are the steering angles of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

n_1 , n_2 , n_3 , and n_4 are the speeds of rotation of the right front wheel, left front wheel, right rear wheel, and left rear wheel, respectively;

L is the distance between each wheel and a center line X between the front wheels and rear wheels;

W is the distance between each wheel and a center line Y between the left wheels and right wheels; and

α_o , which is used as the steering command value, is the angle formed between the center line Y between the left and right wheels of the vehicle, and the direction of travel of the point Po, which is the center point on a line connecting the left and right front wheels.